PACIFIC SPECIES OF GALAXAURA
II. SEXUAL TYPES

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

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INTRODUCTION

BECAUSE of space limitation the first part of this paper, dealing with the asexual forms of Galaxaura in the Pacific, was separated from this second part, which covers the sexual forms. No real harm was done by the separation, because the sexual and the asexual forms of each species have not been associated with certainty as alternating phases in the life cycles of the actually existing natural species. The sexual and the asexual phases differ not only in the reproductive organs that they bear, but also in certain anatomical features that are restricted to one phase or the other. Consequently many more species are of necessity recognized than actually exist. When life-history studies shall have shown which sexual and asexual forms are to be associated, such an investigation as this will cease to be justifiable.

The goal of systematic studies of Galaxaura (and of other genera as well) is to unify and complete our knowledge of the natural species. Every proved association will eliminate a name from the literature, and eventually there will remain only a minimum number of species known only in one phase. In the meantime, however, primary division into sexual and asexual forms, with keys to each series, will prove the most practical and effective way of systematizing the types of the genus.

KEY TO THE SEXUAL FORMS OF GALAXAURA IN THE PACIFIC

SEXUAL TYPES

Plants sexual or cystocarpic; branches terete throughout or flattened above, villous or glabrous; cortical tissue parenchymatous, composed of a continuous

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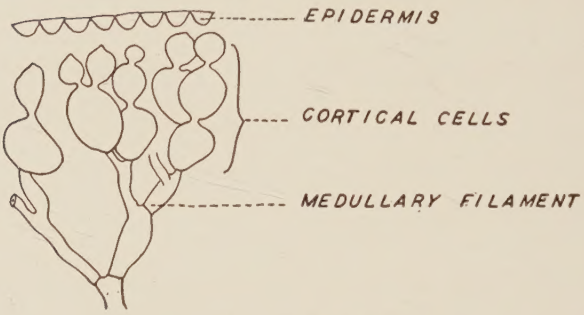

FIG. 1. Type of the Oblongatae

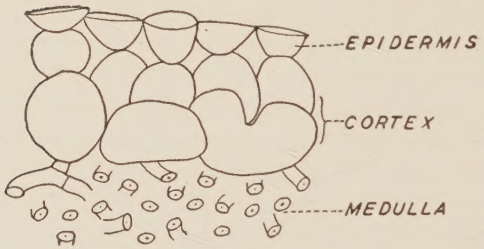

FIG. 2. Type of the Squalidae

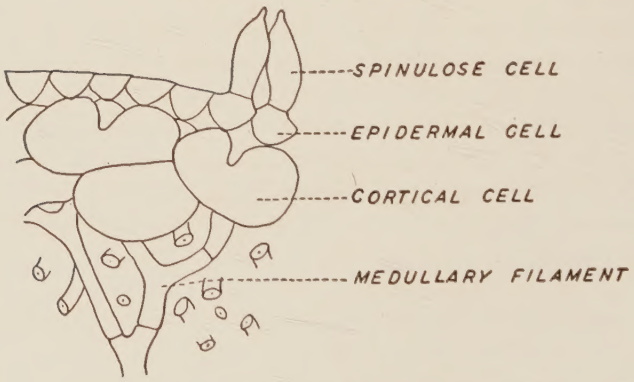

FIG. 3. Type of the Vepreculae

epidermis of chromatophore-bearing cells and a hypodermis of two or three layers of cortical cells which are either loosely arranged and subfilamentous as typified by the Oblongatae[1] (Fig. 1) or compactly and parenchymatously as ex-

[1] With regard to the innovations in sectional nomenclature, necessitated by the inconsistent and incorrectly formed names previously used, see Part I, p. 37.

emplified by the Squalidae (Fig. 2), the Vepreculae (Fig. 3), and the Angustifrondes.

1. Plants with branches terete throughout; cortical tissue with or without lobed cells, when present the latter innermost 2
1. Plants with branches flattened above, although terete below; lobed cells when present intermediate in position..... 7

2. Branches glabrous or subglabrous; cortical tissue parenchymatous or subfilamentous 3
2. Branches villous or hirsute; cortical tissue tristromatic; lobed cells present ..... (Section Squalidae) 6

3. Cortical tissue subfilamentous, remaining attached to medullary filaments after decalcification ..... (Section Oblongatae) 4
3. Cortical tissue parenchymatous ..... (Section Umbellatae) 5

4. Branches slender, commonly 0.5–1.0 mm., seldom exceeding 1 mm. in diameter ..... *G. cylindrica*
4. Branches coarse, 0.8–2.5 mm., commonly exceeding 1 mm. in diameter *G. oblongata*

5. Segments short, annulate-rugose, 1–2 mm. in diameter, seldom exceeding 5 mm. long, nodes constricted ..... *G. rugosa*
5. Segments long, smooth, 2–4 mm. in diameter, 0.5–2.5 cm. long, nodes articulate ..... *G. umbellata*

6. Branches hirsute; extended assimilatory filaments scattered singly, slightly stiff and brittle; epidermal cells 24–44 μ in diameter (surface view) ..... *G. glabriuscula*
6. Branches villous, at least below; extended assimilatory filaments often fasciculate; epidermal cells 12–24 μ in diameter (surface view) *G. squalida*

7. Epidermis bearing spinulose cells; cortical tissue with lobed cells present ..... (Section Vepreculae) 8
7. Epidermis smooth, without spinulose cells; cortical tissue with or without lobed cells ..... (Section Angustifrondes) 9

8. Thallus chalky, strongly spinulose, 1–2 mm. wide ..... *G. veprecula*
8. Thallus smooth, surface shiny, spinulose on the thickened margins only, 2–3 mm. wide ..... *G. ventricosa*

9. Cortical tissue tristromatic, lobed cells present; segments short, commonly not exceeding 1 cm. long ..... *G. angustifrons*
9. Cortical tissue 3- to 4-stromatic, without lobed cells; segments 1.0–2.5 cm. long ..... *G. intermedia*

Galaxaura cylindrica (Ell. & Sol.) Lamouroux. — Pl. I, Figs. 1–12; Pl. VIII, Fig. 1

Corallina cylindrica Ellis & Solander, 1786, p. 114, pl. 22, fig. 4; *Galaxaura cylindrica* Lamouroux, 1812, p. 22, pl. 22, fig. 4; Kjellman, 1900, p. 64, pl. 8, figs. 34–42, pl. 20, fig. 53; Børgesen, 1916, p. 106; 1927, pp. 77–78; Taylor, 1928, p. 138.

Plants densely bushy, up to 10 cm. or more high, attached to the substratum by a discoid holdfast; basal part short-caulescent, upper branches erect, angles narrow, more or less regularly dichotomous, sometimes subpinnate and subexcurrent, with main axes slightly coarser than the lateral ones; segments 5 to 10 mm. long, 0.5 to 1.0 mm. in diameter, terete, faintly rugose; proliferations single or stellate; medullary filaments 8 to 11 μ in diameter, toward the periphery closely and anticlinally branched with each ultimate branch terminated by two or three large subglobose or ellipsoidal closely arranged cells forming a pseudoparenchymatous cortical tissue; cells of pseudoparenchyma gradually diminishing in size outward; cells of the innermost layer subglobose or sometimes compressed and orbicular, 18 to 24 μ in diameter, each bearing one or two ellipsoidal or subglobose cells toward the outside, 5 to 25 μ high, 10 to 18 μ broad, often taller than wide, each in turn bearing one or two small subglobose cells 7 to 11 μ in diameter, forming a subepidermal layer; cells of the outermost layer (epidermis) strongly laterally coherent, parenchymatous, peeling off readily in sheets after decalcification, angular in surface view, semilunate in section, 8 μ high, 10 to 12 μ wide at the outer wall, chromatophore-bearing; conceptacles globose, embedded in the thallus, discharging by ostioles. (The specimens bear only immature reproductive bodies.)

The distinction between *G. cylindrica* and *G. oblongata* seems rather arbitrary, for the two plants are anatomically so similar that even experts fail to point out any noteworthy differentiating features that can be counted as valid specific characteristics. They are separated entirely on the basis of the diameter of the branches, that is, in *G. cylindrica* the branches are very slender, commonly not exceeding 1 mm. in diameter, whereas *G. oblongata* has branches from 1 mm. up in diameter. This characteristic alone naturally is hardly adequate for specific distinction; phycologists generally seem to agree, however, in accepting these two classical species, even when they do not agree upon accepting the numerous "Eugalaxaura" species proposed by Kjellman. Therefore the present identification of species from the Philippine Islands is likewise based solely on the relative diameter of the branches in matèrial referred respectively to *G. cylindrica* and *G. oblongata*.

Kjellman, Børgesen, and others have all reported that the branches of *G. cylindrica* range from 0.5 to 0.75 mm. in diameter, a measure-

ment which is less than I have found in the Philippine plants, in which at least some of the branches reach 1 mm. However, when compared with other plants which I have called *G. oblongata*, the branches of these plants are definitely more slender; therefore I have decided to set the boundary between these two closely related species at 1 mm. If the slightly greater diameter of the Philippine plants holds good when more material comes to light, further studies may indicate that West Indian and Philippine plants are distinguishable.

Type locality. — West Indies.

Specimens studied. — PHILIPPINE ISLANDS: Dalupiri Island, Babuyan Group, *Bartlett 14981*, Oct. 31 — Nov. 5, 1935; Batan Island, Batanes Group, *Bartlett 15416*, July 20, 1935.

Further distribution. — Bermuda, West Indies, warmer Atlantic coast of America, Red Sea.

Galaxaura oblongata (Ell. & Sol.) Lamouroux. — Pl. II, Figs. 1–16; Pl. III, Figs. 1–14; Pl. IX, Figs. 1–2

Corallina oblongata Ellis & Solander, 1786, p. 114, pl. 22, fig. 1; *Galaxaura oblongata* Lamouroux, 1816, p. 262; Børgesen, 1927, pp. 71–77, figs. 39–41; Taylor, 1928, p. 139, pl. 21, fig. 5; 1941, p. 95; 1942, p. 84; 1945, pp. 142–143.

Plants forming dense round tufts 4 to 12 cm. or more high, attached by small discoid holdfasts; branching regularly dichotomous; branches fastigiate or spreading, glabrous, distinctly calcified, brittle and fragile when dried; segments cylindrical, 0.4 to 2.5 cm. long, 0.8 to 2.5 mm. in diameter, more or less annulately rugose, nodes fractured, constricted, or subarticulate, the diameter of the branches in a single plant uniform, but varying greatly between plants; proliferations common, single or stellate, present at nodes or internodes where the epidermis is ruptured; medullary filaments 4 to 12 μ in diameter, toward the periphery anticlinally and closely branched, each ultimate branchlet terminated by two to three subglobose cortical cells (excluding epidermal cells), connected successively by a narrow protoplasmic strand, thus cells of each branchlet remain attached after decalcification, the inner one or two cortical cells the largest, the basal cell subglobose or slightly compressed, wider than high, 20 to 40 μ in diameter, each bearing two cells, rarely a single oblong, obovate, or subglobose one, 16 to 36 μ tall, 12 to 32 μ wide, these in turn each bearing one, sometimes two small, subglobose cells, 8 to 18 μ in diameter, below the epidermis; epidermal cells closely arranged,

peeling off in sheets after decalcification, in surface view angular, 8 to 20 μ in diameter, in section semilunate; reproductive bodies common, male and female conceptacles globose, embedded in the cortical tissue, opening outwardly by an ostiole; spermatangia small, globose, about 4 μ in diameter, or elliptical, 20 μ long, 6 μ in diameter; female conceptacles large; production of first carposporangium sometimes followed by proliferation of a new carposporangium within the empty sporangial wall, and several sporangia may be successively proliferated as the growing season progresses; mature carposporangia large, oval or obpyriform, size variable, 16 by 20 μ to 50 by 70 μ in diameter.

From the numerous specimens examined I noted that some are so very fragile (*Bartlett 14248*) that they could easily be called *G. fragilis;* some have fastigiate branches which would go nicely with *G. fastigiata;* and some have very coarse branches which do not look the least like the others except for their anatomical structure. When I laid them all out, however, I found the variations overlapping. There are specimens of intermediate types to bridge over the extremes, so that it is impossible to draw any specific line that would include one and not exclude another.

If geographical distribution or range of these plants were to play a rôle in the determination of the species, then the plants from the Philippine Islands might be called *G. fastigiata*, since it is the type region for that species. However, my observations have led me to think that *G. fastigiata* is probably a physiological form, that is, the plant may have been grown under such favorable conditions that all the branches received equal chances for development, and therefore became equally tall, so that when pressed they appeared fastigiate. Under less favorable conditions, on the contrary, when normal growth is being constantly interrupted the branching becomes subpinnate, and the branches are unequal in length and in diameter. Both of these states have been observed among the Philippine plants at hand. Furthermore, under *Bartlett 14980* there are the robust, the fastigiate, and the subpinnate forms, all merging into one another along a gradient which would allow sufficient variation for different phases to be considered different species if one met them singly. Besides, there are two specimens, *Bartlett 16185* and *16200*, from Cebu Island, which externally do not look the least like any other *G. oblongata* from the vicinity. The plants are small, heavily calcified, with short poculiform or club-shaped internodes; so that at

first I was strongly inclined to treat them as new, but when carefully examined they were found to be only young plants structurally identical with those of *Bartlett 14980*, which I have called *G. oblongata*.

Because of the structural similarity I regarded the Oblongatae at hand whose branches exceed one millimeter in diameter as *G. oblongata*, and those below one millimeter as *G. cylindrica*. *G. oblongata*, as I have interpreted it, may in the future turn out to be species complex, embracing the sexual phases of more than one species, or perhaps even the species of a distinct genus or subgenus with several haplobiontic species. However, it must be admitted that at present it is not possible to segregate them.

Type locality. — "West Indies."

Type specimen. — "Ellis and Solander's specimen no longer exists."

Specimens studied. — MEXICO: Near Isla María Magdalena, dredged at depths of 5.5 and 21.5 meters, *Taylor 39–667A* and *39–653*, May 9, 1939; ECUADOR: Bahía San Francisco, Esmeraldas, *Taylor 34–485*, Feb. 11, 1934; PHILIPPINE ISLANDS: Dalupiri Island, Babuyan Group, *Bartlett 14607*, July 17; and *14980*, Oct. 31—Nov. 5, 1935; Luzon, Subic Bay, Subic, Zambales Province, *Bartlett 14140*, May 31, 1935; Sinait, Ilocos Sur Province, *Bartlett 14237*, *14248*, June 2, 1935; *Moises Kalaw 6*, June 12, 1935; Cavite Province, *Bartlett 14585*, July 7, 1935; Wawa, Nasugbu, Batangas Province, *J. V. Santos 120*, July 14, 1935; Mindoro, Puerto Galera, *Bartlett 13778*, *13785*, May 12–17, 1935; Cebu Island, Liloan Beach, *Bartlett 16185* and *16200*, Sept. 20, 1935; JAVA: Eiland Kerkhof, Baai van Batavia, *Kostermans 32*, Sept. 26, 1938; SUMATRA: Belimbing (south coast of Sumatra), *Kostermans 773*, Oct. 20, 1938.

Further distribution. — Florida, Dry Tortugas, West Indies, Brazil, Adriatic Sea, Red Sea, Australia, Timor, Hainan Island, Hong Kong, Japan.

Galaxaura squalida Kjellman. — Pl. IV, Figs. 1–11; Pl. VIII, Fig. 2

Kjellman, 1900, pp. 55–56, pl. 6, figs. 1–12, pl. 20, fig. 9; Børgesen, 1916, pp. 102–105, figs. 108–111; Taylor, 1928, p. 140, pl. 21, fig. 18, pl. 31, fig. 4; 1942, p. 84; 1945, p. 142.

Plants bushy, up to 10 cm. or more high, attached by a broad discoid holdfast; branching dichotomous, angles narrow or acute;

branches terete, villous, the upper more or less glabrous; segments 0.5 to 2.0 cm. long, 1 to 2 mm. in diameter, annulate-rugose, basal ones often short, closely forking (the branches thus appearing quasi-umbellate); proliferations solitary or geminate, base cupuliform; extended assimilatory filaments fasciculate, fascicles evenly distributed or subverticillate toward the apex of the branches, seldom exceeding 1 mm. long, diameter 15 to 18 μ, composed of short cylindrical cells 1.5 to 2.0 times as long as broad; medullary filaments 7 to 18 μ in diameter, cortical tissue parenchymatous, tristromatic; cells of the innermost layer the largest, more or less globose, 22 to 40 μ in diameter, some 2- or 3-lobed, and their diameter one to two times wider than high; cells of the intermediate layer smaller, globose or ovate, 18 to 25 μ in diameter; cells of the outermost layer (epidermis) closely arranged, of two kinds: either (*a*) angular in surface view, 14 to 22 μ in diameter, in section semilunate, 10 to 15 μ tall by 18 to 25 μ broad at the outer wall; or (*b*) circular and slightly elevated above the general level of the surface (these may be the basal cells of extended assimilators identical with what others call "abortive cells"); conceptacles spherical, embedded in the medullary layer, with ostioles opening through the cortical tissue; carposporangia ovate or elliptical, about 50 μ long by 30 μ in diameter.

In the section Squalidae (Microthoë) Kjellman distinguished a West Indian plant as *G. squalida* and a Japanese plant as *G. cuculligera;* the latter is characterized by having cucullate proliferations. This segregation has been adopted by most modern workers, and the plants from Pacific waters recorded under the name *G. cuculligera* (as, for example, by Weber–van Bosse, Butters, Tanaka), and those from the Atlantic as *G. squalida* (by Collins and Hervey, Howe, Børgesen, Taylor).

The presence of *G. cuculligera* has been recorded by Japanese workers, but the occurrence of *G. squalida* in the Pacific Ocean, so far as I can trace it, has not hitherto been noted. Nevertheless, in the Philippine materials that I have examined there are some plants which bear cucullate branches and others which do not. Structurally, however, I have not been able to detect any noteworthy differences between the two, so that, presumably, the cucullate condition may have been brought about by a sudden interruption of the normal rate of growth. This condition is evident in *Bartlett 14982*, for here one can readily see that the older part of the plant is very muddy. It

seems that the plant was for a time buried in mud or covered by it and that the new growth regenerated from the center of the axis, so that the basal part was surrounded by the peripheral tissue of the older branch — a state which is similar to regeneration of the lost parts. Furthermore, since the cucullate state also appears on the West Indian plants, as well as being common to other species of Squalidae, since it is absent in some of the Philippine plants, and since microscopical examination yields no evidence for the separation of the two forms, I am in this case adopting a broader view of the species and refer these Philippine plants to *G. squalida*, viewing the cucullate condition in some specimens as ecological or physiological and regarding it as having been brought about by external factors.

Type locality. — St. Croix, Virgin Islands.

Type specimen. — In Areschoug's herbarium, under the name *G. rugosa*.

Specimens studied. — Philippine Islands: Dalupiri Island, Babuyan Group, *Bartlett 14982*, Oct. 31—Nov. 5, 1935; Lubang Island, Mindoro, *Villaflores 6*, *7*, *8*, Aug. 24, 1935; Society Islands: Tahiti, *Brooks* in Taylor herbarium *20495*, Dec., 1932; Panama: Bahía Honda, *Taylor 39–130*, March 26, 1939.

Further distribution. — Bermuda, Florida, Bahamas through the West Indies to the Virgin Islands.

Galaxaura glabriuscula Kjellman. — Pl. IV, Figs. 14–20; Pl. X, Fig. 1

Kjellman, 1900, p. 56–77, pl. 7, figs. 1–2, pl. 20, fig. 26; Butters, 1911, pp. 175–176; Tanaka, 1936, pp. 151–152, figs. 12–13, pl. 37, fig. 1.

Plants with branches up to 9 cm. or more high, the basal attachment not seen; branches often much crowded above, forming corymbose or flabelliform tufts; the lower part hirsute, the upper sparingly hairy or often subglabrous, apex smooth and glabrous; segments ranging from 2 or 3 mm. to 15 (or more) mm. long, 0.8 to 2.0 mm. in diameter; proliferations solitary, base cucullate, inconspicuously encircled by a tuft of extended assimilatory filaments; the central axis traversed by few loosely entangled filaments 7 to 16 μ in diameter; cortical tissue parenchymatous, tristromatic, about 80 μ thick; cells of the innermost layer the largest, subglobose, often slightly wider than high, diameter 30 to 48 μ, some 2- or 3-lobed, one or two times

wider than high; cells of the intermediate layer smaller, subglobose, loosely arranged with intercellular spaces filled with lime, diameter 28 to 44 μ, containing stellate chromatophores each with a pyrenoid at the center; cells of the outermost layer forming the epidermis, closely arranged, parenchymatous, angular in surface view, 28 to 36 μ in diameter, in section semilunate, 12 to 16 μ tall, 28 to 40 μ wide, including the outer wall; extended assimilatory filaments evenly distributed, slightly stiff and thus easily fractured, shaft simple or branched, basal part 15 μ, apical part 18 μ in diameter, cells one and one half to two times as long as the diameter; hair-bearing epidermal cells slightly raised above the level of the surrounding epidermal cells, circular in surface view, with a circular perforation when the hair becomes detached; conceptacles spherical, embedded in the thallus, discharging through small ostioles; carpospores clavate or pyriform.

The Javanese plants which I assign to *G. glabriuscula* are very much like *G. squalida* in habit, but differ anatomically in the following respects:

The epidermal cells of *G. glabriuscula*, in general, are larger than those of *G. squalida*, that is, those of the former commonly range from 28 to 44 μ in diameter, whereas those of the latter rarely exceed 20 μ in diameter. The lobed cortical cells in *G. glabriuscula* are more common and larger than those of *G. squalida*. The extended assimilatory filaments of *G. glabriuscula* are few, thinly scattered, relatively stiff and brittle in texture when compared with those of the closely related species. Lastly, the presence of yellow pigment in the chromatophores has been regarded by several writers as unique in this species.[2]

The yellow color, however, is not particularly noticeable in the present Javanese plants, but microscopical examination does show the presence of a yellowish tinge in the chromatophores. If it should prove that the species is characteristically yellow, then the yellow-tinted chromatophore in these plants indicates that they did contain

[2] Ordinarily I am not much in favor of using color as a criterion for specific determination in Galaxaura, but since the presence of a yellow pigment has been mentioned by every author who describes *G. glabriuscula* and since this yellow color is different from other pigments which one finds in the red algae, I have tentatively decided to accept a color character in this case and have assigned these plants from Java to *G. glabriuscula*. It is possible, if the presence of yellow pigment is alternative to the presence of red in the red algae, that there may be other yellow types, perhaps yellow varieties or ecological variants of red species.

yellow pigment, but failed to retain more than a trace of it because they were preserved in formaldehyde before mounting.

Type locality. — Tahiti.

Type specimen. — In Areschoug's herbarium under the name *Galaxaura rugosa.*

Specimens studied. — Java: Eiland Kělapa, Duizend-eilanden, *Kostermans 254,* Oct. 5, 1938.

Further distribution. — Bonin Islands, Tahiti, Hawaiian Islands.

Galaxaura rugosa (Ell. & Sol.) Lamouroux. — Pl. IV, Figs. 12–13; Pl. X, Fig. 2

Kjellman, 1900, p. 55; Børgesen, 1915–20, p. 100, figs. 105–106; Howe, 1920, p. 558; Taylor, 1928, p. 140, pl. 21, fig. 16, pl. 30, figs. 2, 10; 1941, p. 95; 1942, p. 84.

Plants up to 4 cm. high; branching regularly dichotomous; segments short, 2 to 5 mm. long, 1 to 1.5 mm. in diameter, terete, glabrous, distinctly annulate–rugose, continuous or constricted at the nodes; medulla composed of loosely entangled filaments 7 to 15 μ in diameter; the cortical tissue tristromatic, cells of the innermost layer largest, some 2- or 3-lobed, others globose or subglobose, often slightly wider than tall, 20 to 40 μ high, 30 to 40 μ in diameter; cells of the intermediate layer smaller than the inner ones, subglobose or obovate, 25 to 30 μ tall, 15 to 22 μ in diameter, containing stellate chromatophores with a pyrenoid at the center; cells of the outermost layer (epidermis) angular in surface view, 18 to 26 μ in diameter, in section semilunate, 8 to 15 μ tall, 18 to 22 μ in diameter, containing well-developed chromatophores; conceptacles spherical, embedded in the thallus, with ostioles opening through the thin cortical parenchymatous tissue; reproductive bodies immature.

The determination of this single specimen from Batan Island, Philippines, may seem unnatural, for it is commonly accepted that *G. rugosa,* based on a plant from Jamaica, is limited to the Atlantic waters, and similar Pacific plants have been given the name *G. elongata.* According to the type description, however, Agardh's *G. elongata,* based on plants from Tonga and Australia, was much taller and larger than *G. rugosa.* It was described as 3 to 6 inches tall, with branches as thick as a "crow's quill," whereas the present Philippine plant is only 3 to 4 cm. high, with branches commonly 1.0 to 1.5 mm in diameter.

As for Lamouroux's *G. rugosa*, it was based on Ellis and Solander's plant from the Jamaican coast, which was well illustrated by Plukenet (1691, pl. 168, fig. 4). Having compared the Batan Island plant with Plukenet's illustration of the Jamaican plant, without the least doubt I consider this Philippine plant to be identical with the West Indian one and therefore it is referred to *G. rugosa* (Ell. & Sol.) Lamouroux.

Opinion of taxonomists in the field seems to agree that *G. rugosa* is distinguished from other closely related species of the Rugosae in having branches distinctly annulate–rugose and more or less glabrous, with little or no development of extended assimilatory filaments. The present determination of a single specimen from Batan Island is based upon these two characteristics.

This Philippine plant (*Bartlett 15410*) agrees closely with Børgesen's description of the West Indian plant, except that it is very smooth, without any visible extended assimilatory filaments. Microscopical examination of the epidermal cells shows, however, the presence of circular cells which are slightly raised above the level of the angular epidermal cells and suggests potential or abortive basal cells corresponding to extended assimilatory filaments.

The branching of *G. rugosa* is very regularly dichotomous, being much more regular than that of the closely related species *G. glabriuscula* and *G. squalida*. In texture the plant is rather delicate, with wall of the thallus thinly membranous, and therefore rather fragile after decalcification.

Type locality. — Jamaica, British West Indies.

Specimens studied. — Philippine Islands: Beach at Basco, Batan Island, *Bartlett 15410*, July 20, 1935.

Further distribution. — Florida, Bahamas through the West Indies to the Virgin Islands.

Galaxaura umbellata (Esp.) Lamouroux. — Pl. V, Figs. 1–6; Pl. XI, Fig. 1

Tubularia umbellata Esper, 1830,[3] p. 125, Tubularia, pl. 17, figs. 1 2; *Galaxaura umbellata* Lamouroux, 1812, p. 185; Lamouroux, 1816, p. 262; J. G. Agardh, 1876, p. 526; Kjellman, 1900, p. 88 (only the name mentioned).

[3] *Tubularia umbellata* was cited by Lamouroux (1812) as having been published in "Esper Zooph., tab. 17, fig. 1-2." I have not been able to obtain this work, and so cannot give the exact title and date. However, both the descrip-

Plants forming tufts 5 to 6 cm. high; branches terete, glabrous, fastigiate, one to three or more times dichotomous, angles narrow and branches erect; thallus thin-walled, membranous, slightly nitent, segments 0.5 to 3.0 cm. long, 2 to 4 mm. in diameter, subarticulate or strongly constricted at the nodes; apex round with the growing point restricted to a tiny perforation in the center; medulla traversed by few loosely interwoven filaments 7 to 16 μ in diameter, cortical tissue tristromatic, cells of the innermost layer the largest, often compressed, more or less rectangular in section, commonly wider than high, 40 to 90 μ in diameter, 30 to 36 μ tall; cells of the intermediate layer variable, some subrectangular, like those of the innermost layer, some subglobose, 18 to 22 μ high, 20 to 40 μ wide; cells of the outermost layer closely arranged, forming an epidermis, in surface view angular, 20 to 30 μ in diameter, in section semilunate, 8 to 15 μ high, 20 to 30 μ wide, containing well-developed stellate chromatophores with a large pyrenoid in the center; conceptacles very young, reproductive bodies immature.

Practically no difficulty has been encountered in referring this plant to its proper section, because both the anatomical structure of the thallus and the presence of the sexual reproductive bodies place it clearly in the Umbellatae (= Kjellman's Dichotomaria, Spissae). There is a problem, however, in assigning the plant to the proper species, for in his monograph Kjellman recognizes a total of six undistinguished species under "Spissae," namely, *G. obtusata* Lamouroux (*Corallina obtusata* Ell. & Sol.), *G. umbellata* Lamouroux (*Tubularia umbellata* Esper), *G. Decaisnei* Agardh, and his three newly established species, *G. tumida*, *G. insignis*, and *G. corymbifera*. In maintaining the older and proposing the new species he did not present any clear-cut specific characters and, in fact, for the old species did nothing more than merely mention the names, without giving diagnostic characteristics.

Because of their great structural similarity the Umbellatae are separated almost entirely by external differences, such as the general habit of the plants and the length and diameter of the internodes. All these external characteristics are highly subject to environmental,

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tion of *Tubularia umbellata* and the plate of figures were republished in Esper's *Die Pflanzenthiere* in 1830, eighteen years after the appearance of Lamouroux's *Histoire des polypiers coralligènes flexibles vulgairement nommés zoophytes*, to which the present reference is made.

physiological, or developmental modification and, therefore, taxonomists have different opinions about the validity of the species which have been proposed. The two classical species, *G. umbellata* and *G. obtusata*, were recognized by early workers, whereas in modern publications only *G. obtusata* has been recorded.

These plants from Dalupiri, Philippine Islands (*Bartlett 15022*), agree very closely in height and in length and diameter of the internodes with Esper's illustration of *G. umbellata* from the East Indies; therefore I do not hesitate to place them with *G. umbellata*. This decision cannot be called arbitrary, for the Philippine Islands and the East Indies are within the geographical range of many species. Also, since *G. umbellata* took the lead in the first list of the Galaxaura species, in 1812, it might be considered the generic type ("standard species"), and therefore not to be thrown into synonymy, as was done by Børgesen.

Type locality. — East Indies, according to Kjellman.

Specimens studied. — Philippine Islands: Dalupiri Island, Babuyan Group, *Bartlett 15022*, Oct. 31–Nov. 5, 1935.

Further distribution. — Africa (Port Natal), Australia, West Indies, tropical Atlantic Ocean.

Galaxaura veprecula Kjellman. — Pl. VI, Figs. 1–8; Pl. XII, Fig. 1

Kjellman, 1900, pp. 80 81, pl. 16, figs. 17–33, pl. 20, fig. 20; Yendo, 1918, p. 66; De Toni, 1924, p. 137; Tanaka, 1936, pp. 169–170, figs. 36–37, pl. 43, fig. 1; Taylor, 1945, p. 143.

Plants briefly caulescent, up to 8 cm. or more high, attached to the substratum by a broad discoid holdfast; caudex villous, upper branches widely effuse or flabelliform, distinctly flattened, branching regularly or subregularly dichotomous, sometimes subpinnate with branches unilaterally developed, thus causing the main axes to arch; internodes continuous, sometimes subarticulate and proliferous, 0.5 to 1.2 cm. long, 1 to 2 mm. in diameter, cuneate or subcuneate; thallus smooth and slightly shiny where there are no spinulose cells, but dirty-chalky and farinaceous where covered by spinulose cells; proliferations common, each encircled at the base by a tuft of extended assimilatory filaments 1.0 to 1.5 mm. long; medullary filaments 7 to 12 μ in diameter, cortical tissue tristromatic, 48 to 80 μ thick; cells of the innermost layer subglobose or compressed, often

wider than high, 20 to 30 μ tall, 35 to 45 μ broad, cells of the intermediate layer very large, subglobose, 22 to 30 μ tall, 25 to 40 μ broad, some 2- to 3-lobed, in diameter two or three times broader than tall, cells of the outermost layer (epidermis) chromatophore-bearing, in surface view angular, 16 to 28 μ in diameter, in section semilunate, 10 to 15 μ tall, 8 to 20 μ broad at the outer edge; spinulose cells occurring in patches, irregularly scattered over the surface of the thallus, commonly appearing on the thickened margins first, easily rubbed off or deciduous, clavate or elongate–spatulate, 25 to 35 μ tall, 12 to 15 μ in diameter, apex pointed or mucronate; conceptacles spherical, embedded in the thallus, each opening outward by an ostiole; female plants often with cystocarpic ostioles opening on or near the thickened margins of the thallus; carpospores ovoid or pyriform, 20 to 25 μ by 35 μ in diameter; male conceptacles more numerous, ostioles evenly scattered all over the surface of the thallus; spermatia very small, about 4 μ in diameter.

Superficially this species is almost inseparable from the nonsexual plants of section Arboreae, and likewise from smooth sexual Angustifrondes, and they are often found in the same collection in herbaria, or in nature growing with the tetrasporic plants of Arboreae, thus indicating intimate association of the two forms, which has led to Howe's hypothesis of sexual dimorphism of these algae. However, the development of the spinulose cells on the epidermis makes the plants anatomically unique and distinguishable from the smooth species of Angustifrondes.

In the single collection (*Bartlett 15009*) of Philippine plants thirteen of twenty-five specimens are sexual forms, with seven bearing cystocarps, two with spermatangia and four which are anatomically sexual, although no reproductive organs have been observed. The remaining twelve (*Bartlett 15009a*) are anatomically tetrasporic plants belonging to the Arboreae, even though tetraspores have not been found.

Although the nonsexual and the sexual plants do appear superficially identical, nevertheless, when one is familiar with these it is not difficult to distinguish them even without the aid of a low magnifier, for the thallus of the tetrasporic plant is slightly shiny, sometimes even iridescent to a slight extent, so that Børgesen described it as "often smooth and glossy, sometimes shining like mother of pearl."

Type locality. — Indian Ocean, near Madagascar Island.

Type specimen. — In Upsala herbarium under the name *G. marginata.*

Specimens studied. — Philippine Islands: Dalupiri Island, Babuyan Group, *Bartlett 15009*, Oct. 31–Nov. 5, 1935; Batan Island, *Bartlett 15411*, July 20, 1935; Costa Rica: Golfo Dulce, *Taylor 39–90b*, *39–91b*, *39–92b*, March 26, 1939; Ecuador: Isla San Cristóbal, dredged from two to three fathoms, *Schmitt 41C–33*, Jan. 30, 1933.

Further distribution. — Madagascar, Formosa.

Galaxaura ventricosa Kjellman. — Pl. VI, Figs. 9–12; Pl. XII, Fig. 2

Kjellman, 1900, p. 81, pl. 16, figs. 11–16, pl. 20, fig. 24; Taylor, 1945, pp. 143–144.

Plants closely resembling *G. veprecula;* basal attachment not seen; the upper part of the branches strongly flattened, as much as 7.0 to 8.5 cm. high; texture carnose or subcoriaceous–membranous, flattened surface smooth, glabrous, even nitent, ultimate part of branches thin, membranous, or translucent; internodes continuous, rarely constricted or fractured at the base of the forkings, margin thickened, 0.5 to 1.2 cm. long, 2 to 3 mm. wide; proliferations few, when present each encircled at the base by a tuft of extended assimilatory filaments about 1 mm. long; spinulose cells of the epidermis found only on the thickened margins of the thallus; medullary filaments 8 to 15 μ in diameter; cortical tissue parenchymatous, tristromatic, 60 to 75 μ thick (excluding the spinulose cells); cells of the innermost layer strongly compressed, 20 to 36 μ high, 56 to 80 μ broad; cells of the intermediate layer variable in size and in shape, commonly 30 to 36 μ high by 35 to 44 μ broad, subglobose or some 2- or 3-lobed, with the diameter two to three times greater than the height, those below the thickened margins often subcylindrical, twice as tall as broad radially; cells of the outermost layer chromatophore-bearing, forming an epidermis, in surface view angular, 20 to 36 μ in diameter, in section semilunate, 12 to 24 μ high, 24 to 35 μ broad at the outer wall; spinulose cells columnar, fusiform, or elongate–spatulate, 32 to 40 μ high, 12 to 20 μ in diameter (commonly 16 to 18 μ), with the apex rounded or acute, sometimes short-acuminate or slightly mucronate; extended assimilatory filaments at the base of the proliferations 12 to 16 μ in diameter, their tumid basal cells obovoid, elliptical or obpyriform,

48 to 68 μ long, 24 to 32 μ in diameter at the broadest part; shaft cells cylindrical, two to four times as long as broad, containing well-developed chromatophores; conceptacles embedded in the thallus. Plant bearing immature reproductive bodies.

Anatomically *G. ventricosa* is inseparable from *G. veprecula*, but morphologically is distinguished by its broader thallus, with a lesser development of the spinulose cells, which are limited to the margins of the thallus, and the more or less continuous branches with fewer proliferations. The thallus of *G. ventricosa* has a diameter of about three millimeters. Its internodes are nearly equal in diameter throughout, or with the upper end only slightly wider than the lower, whereas those of *G. veprecula* seldom exceed two millimeters in width and the internodes are often cuneate, with the upper end distinctly wider than the lower.

The spinulose cells of *G. veprecula* are irregularly scattered all over the surface of the thallus, but in *G. ventricosa* they are more or less localized on the thickened margins of the thallus. These spinulose cells vary somewhat in size and shape even in the same thallus, and therefore may not have any taxonomic significance at all. Nevertheless, it might be worth while to mention in this connection that in *G. ventricosa* they are generally of slightly larger diameter than in *G. veprecula*.

Type locality. — Near the mouth of Gabon River, Africa.

Specimens studied. — Mexico: Dredged at 21.5 m. depth, near María Magdalena Island, *Taylor 39–652*, May 9, 1939.

Further distribution. — Near Gabon River, Africa.

Galaxaura angustifrons Kjellman. — Pl. VII, Figs. 1–5; Pl. XI, Fig. 2

Kjellman, 1900, p. 82, pl. 15, figs. 11–25, pl. 20, fig. 27; Weber-van Bosse, 1921, p. 219; Taylor, 1945, p. 144.

Plants bushy, up to 9 to 10 cm. high, basal parts of the branches subterete, more or less villous, the upper ones distinctly flattened; branching regularly dichotomous, angles open, rounded or acute; segments short, commonly 5 to 7 mm. long, 1.5 to 2.0 mm. wide, continuous, margins slightly thickened; proliferations few, each encircled at the base by a tuft of extended assimilatory filaments 0.5 to 1.0 mm. long; medullary filaments 8 to 16 μ in diameter; peripheral parenchyma tristromatic, 80 to 100 μ thick; cells of the innermost layer the

largest, subglobose or angular, compressed, 30 to 50 μ high, 40 to 100 μ broad; the intermediate layer composed of subglobose or ovate cells 24 to 38 μ in diameter, and among these are lobed cells two or three times as broad as high; cells of the outermost layer constituting the epidermis, angular in surface view, 20 to 30 μ in diameter, and in section semilunate or hemispherical, 16 to 24 μ tall by 20 to 28 μ wide, containing well-developed chromatophores; extended assimilatory filaments 15 μ in diameter, slightly attenuated toward the apex; tumid basal cell obpyriform or elongate–elliptical, 48 μ long, 28 to 30 μ in diameter; shaft cells 2 or 3 times as long as thick; young filaments few-celled, composed of shorter cells whose apical cells are ovate or round; conceptacles embedded in the thallus, with ostioles opening near the thickened margins of the thallus; reproductive bodies immature.

Superficially *G. angustifrons* is practically inseparable from *G. veprecula;* in structure also the two species show close correspondence in the width and length of the internodes, the presence of the lobed cells in the intermediate layer of the cortical tissue, and in the size of the epidermal cells. However, the presence or the absence of the spinulose cells on the epidermis supplies the specific distinction, that is, *G. angustifrons* is characterized by having a glabrous thallus, whereas *G. veprecula* has a chalky or "dusty" thallus because of the development of the spinulose cells over all the surface or at least on the thickened margins. The cortical tissue of *G. angustifrons* commonly exceeds 80 μ in thickness; that of *G. veprecula* is generally less than 80 μ. In surface view the epidermal cells vary greatly in size and thus afford no distinguishing features.

Type locality. — Bahía, Brazil.

Type specimen. — In Areschoug's herbarium.

Specimens studied. — Ecuador: Isla Santa Cruz, *Schmitt 81B–33,* Feb. 16, 1935.

Further distribution. — Brazil, Java.

Galaxaura intermedia, sp. nov. — Pl. VII, Figs. 6–10; Pl. XIII

Taylor, 1945, pp. 144–145.

Plantae deliquescentes, arborescentes, minus quam 23 cm. altae, disco ad substratum adfixae; caudice partibusque ramorum basalibus

subteretibus, villosis; ramis sursum compressis, glabris; segmentis linearibus, continuis, 1.0–2.5 cm. longis, 1–2 mm. latis, gelatinosis, coriaceis, vix calce incrustatis, siccitate fragilibus, inconspicue transverse striatis, marginibus neve incrassatis neve involutis; filamentis medullariis 10–12 μ diametientibus, cortice parenchymatoso, 3- vel 4-stromatico, minus quam 100 μ crasso, cellulis intimis quam aliis grandioribus, ovoideis vel subrectangularibus, 28–40 μ altitudine, 50–70 μ diametro; cellulis intermediis hypodermaticisque minoribus quam intimis, subglobosis, cellulis epidermatis crasse circumvallatis, angularibus, 12–20 μ diam., in sectione transversali frondis lunatis, 10–18 μ altis, 16–24 μ diam.; liberis filamentis assimilatoriis basi 16 μ, diam., ad apicem versus 18–20 μ, cellulis isodiametricis vel interdum duplo longioribus quam latioribus, absque vel cum cellulis tumidis basalibus; conceptaculis globosis, in thallo immersis, ostiolis ad superficiem aperientibus. Rami carpogoniales desunt.

Specimen typicum. — In loco dicto "Black Beach Anchorage," Insula Santae Mariae, in Insulis Galapagorum, legit W. R. Taylor n. 34–213, Jan. 17–18, 1934; in herb. "Hancock Foundation," Universitatis Californiae Australis; duplum in herbario Universitatis Michiganensis.

Plant tall, as much as 23 cm. or more high, attached by a discoid holdfast, the basal part strongly caulescent, caudex villous, about 2 cm. long, 3 to 5 mm. thick at base; branches dichotomous, angles narrow, acute, slightly villous and subterete toward the base, flattened above, glabrous; segments linear or linear–cuneate, continuous, 1.0 to 2.5 cm. long, 1 to 2 mm. wide, subcoriaceous or carnose–membranous, more gelatinous and less calcified than other known species, brittle when dried; inconspicuously striated, margin neither thickened nor involute; thallus attenuate toward the apex, less than about 1 mm. wide; medullary filaments subequal, 10 to 12 μ in diameter; cortical tissue strongly parenchymatous, 3- to 4-stromatic, about 100 μ thick; cells of the innermost layer the largest, subglobose, rectangular, 28 to 40 μ tall, 50 to 70 μ in diameter, generally wider than tall, cells of the intermediate layers more or less globose, ovate, larger in 1-layered parts than in 2-layered; lobed cells not seen; the outermost layer or epidermis composed of thick-walled cells, angular in surface view, 12 to 20 μ in diameter, in sectional view semilunate, 10 to 18 μ tall, 16 to 24 μ wide; extended assimilatory filaments cylindrical, slightly contracted toward the base, with or without tumid

basal cells; shaft cells 16 to 20 μ in diameter, one to two times as long as wide; conceptacles embedded in the thallus, with ostioles opening on the surface; reproductive bodies immature.

The species is characterized by having a smooth, glabrous thallus whose epidermal cells are free from the development of spinulose cells — a characteristic that is considered by Kjellman a sufficient basis for the separation of sections Angustifrondes (his Laevifrons) and Vepreculae. It may further be distinguished by the very thick outer wall of the epidermal cells, containing a high percentage of gelatinous substance which absorbs moisture readily in damp weather.

The section Angustifrondes has hitherto been composed of only two species, as first proposed by Kjellman. The first species, *G. magna*, is based on plants from Cape Agulhas, Africa, and the other, *G. angustifrons*, on plants from Bahía, Brazil. In the section the Ecuadorian plant seems to have a position intermediate between its two predecessors, for it possesses some characteristics in common with *G. magna* (a species that has been omitted from the present treatment because of lack of material), and some with *G. angustifrons*.

The new species agrees with the description of *G. magna* in almost every respect except for its much narrower branches, which, in fact, are the narrowest in all the three species of the Angustifrondes so far proposed. The thick gelatinous cell wall of *G. intermedia* expands considerably when it comes in contact with moisture. Thus in damp weather, when the humidity of the air is high, the specimen can absorb enough moisture to loosen itself from the herbarium sheet. On the contrary, under dry conditions the thallus becomes rather brittle, like that of Chondrus or Laminaria. Its low content of lime is shown by the release of few bubbles in decalcification.

Among the duplicates under this number (*Taylor 34–213*) I have recently detected one tetrasporic specimen which is identical in structure with the tetrasporic plants (*Taylor 34 -164*) of Santa Maria Island, Galápagos, that I have assigned to *G. spathulata* Kjellm. (Chou 1945, p. 53). Because of the similarity in size of these two forms a suggestion was made in connection with the discussion of *G. spathulata* that a sexual plant which is likewise tall and arborescent might represent the sexual phase of *G. spathulata*. The finding of this tetrasporic plant among the sexual forms further strengthens my presumption that those nonsexual plants treated under the name *G. spathulata* and the sexual plants described under the present new name *G. intermedia*

are representatives of the two phases of one life history. More collecting and study will be necessary to validate this hypothesis.

Specimens studied. — Ecuador: Black Beach Anchorage, Isla Santa Maria, Galápagos Islands, *Taylor 34-213* (type), Jan. 17–18, 1934.

Further distribution. — So far as known, endemic to the Galápagos Islands in the eastern Pacific.

LITERATURE CITED

Agardh, J. G. 1876. Species, genera et ordines algarum. Vol. III. Epicrisis systematis floridearum, vii + 724. Leipzig.

Børgesen, F. 1915–20. The Marine Algae of the Danish West Indies, II. Dansk Bot. Arkiv, 3 : 1–504.

—— 1927. Marine Algae from the Canary Islands. III. Rhodophyceae. 1. Bangiales and Nemalionales. Kongel. Danske Vidensk. Selsk., Biol. Medd., 6 (6) : 1–97.

Butters, F. K. 1911. Notes on the Species of *Liagora* and *Galaxaura* of the Central Pacific. Minn. Bot. Stud., 4 (2) : 161–184, pl. 24.

Chou, R. C.-Y. 1945. Pacific Species of Galaxaura. I. Asexual Types. Pap. Mich. Acad. Sci., Arts, and Letters, 30 (1944) : 35–55.

Collins, F. S., and Hervey, A. B. 1917. The Algae of Bermuda. Proc. Am. Acad. Arts and Sci., 53 : 3–195.

De Toni, G. B. 1924. Sylloge algarum omnium hucusque cognitarum. Vol. IV, Sylloge floridearum: Additamenta, xi + 767, Patavii.

Ellis, J., and Solander, D. 1786. The Natural History of Many Curious and Uncommon Zoophytes Collected from Various Parts of the Globe, xii + 208, 63 pls.

Esper, E. J. C. 1830. Die Pflanzenthiere in Abbildungen nach der Natur mit Farben erleuchtet nebst Beschreibungen. Dritter Theil. Nürnberg.

Howe, M. A. 1920. Algae, pp. 553–618. *In* N. L. Britton and C. F. Millspaugh, The Bahama Flora, viii + 695. New York.

Kjellman, F. R. 1900. Om Floridé-slägtet *Galaxaura* dess organografi och systematik. Kongl. Svensk. Vetensk.-Akad. Handl., 33 (1) : 1–110, pls. 1–20.

Lamouroux, J. V. F. 1812. Zoophytes flexibles, ou coralligènes non entièrement pierreux. Nouveau Bulletin des Sciences, par la Société philomatique de Paris, 3 : 182–188.

—— 1816. Histoire des polypiers coralligènes flexibles, vulgairement nommés zoophytes, lxxxiv + 559, pls. 1–19.

Plukenet, L. 1691. Phytographia, pl. 168, fig. 4. London.

Tanaka, T. 1936. The Genus *Galaxaura* from Japan. Sci. Pap. Alg. Res., Fac. Sci., Hokkaido Imp. Univ., 1 (2) : 141–173, pls. 34–45.

Taylor, W. R. 1928. The Marine Algae of Florida with Special Reference to the Dry Tortugas. Pap. Tortugas Lab., Carnegie Inst. Wash., 25 : 1–219, pls. 1–37.

—— 1941. Tropical Marine Algae of the Arthur Schott Herbarium. Field Museum of Nat. Hist., Bot. Ser. 20, 4 : 87–104, pls. 1–2.

—— 1942. Caribbean Marine Algae of the Allan Hancock Expedition. The University of Southern California Publications Allan Hancock Atlantic Expedition, Report Number 2, p. 1–193, pls. 1–20.

—— 1945. Pacific Marine Algae of the Allan Hancock Expeditions to the Galapagos Islands. Allan Hancock Pacific Expeditions, 12 : iv + 528 (Chaetangiaceae, pp. 136–148).

Weber–van Bosse, A. 1921. Siboga-Expeditie. Liste des algues du Siboga. II, Rhodophyceae, première partie, Protoflorideae, Nemalionales, Cryptonemiales. Monographie LIXb de Uitkomsten op zoologisch, botanisch, oceanographisch en geologisch gebied verzameld in Nederlandsch Oost-Indië 1899–1900 aan boord H. M. "Siboga" onder commando van Luitenant ter zee 1e kl. G. F. Tydeman. Leiden.

Yendo, K. 1918. Notes on Algae new to Japan. VIII. Bot. Mag. Tokyo, 32 : 65–81.

EXPLANATION OF PLATE I

Galaxaura cylindrica

Fig. 1. Surface view of epidermis. × 340

Fig. 2. Section of portion of thallus. × 340

Figs. 3–4. Hypodermal and cortical cells. × 610

Figs. 5–6. Medullary filaments bearing cortical cells. × 340

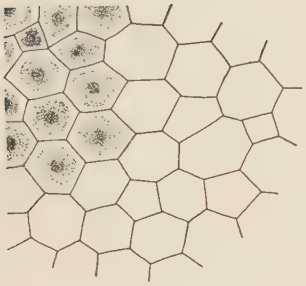
Figs. 7–8. Short free ends of filaments at fractured nodes. × 340

Fig. 9. Spermatangia with spermatia. × 610

Fig. 10. Young branched filaments inside spermatangium. × 610

Fig. 11. Spermatangial branches, showing some spermatangia, with secondary or tertiary spermatangia developed within old walls. × 610

Fig. 12. Young spermatangia and young branching filament. × 610



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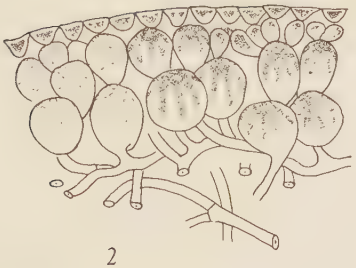

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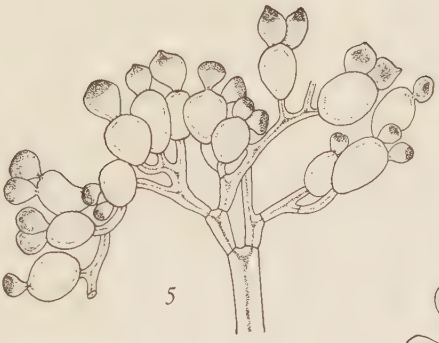

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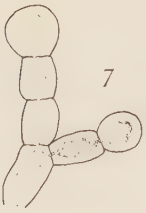

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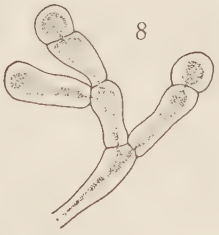

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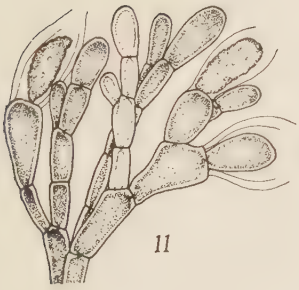

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EXPLANATION OF PLATE II

Galaxaura oblongata

FIG. 1. Epidermis, surface view. × 340

FIGS. 2–4. Medullary filaments bearing cortical cells. × 340

FIG. 5. Habit of conceptacle removed from thallus. × 80

FIG. 6. Cluster of branching filaments inside the conceptacle. × 340

FIGS. 7–9. Sporogenous filaments with carposporangia. × 340

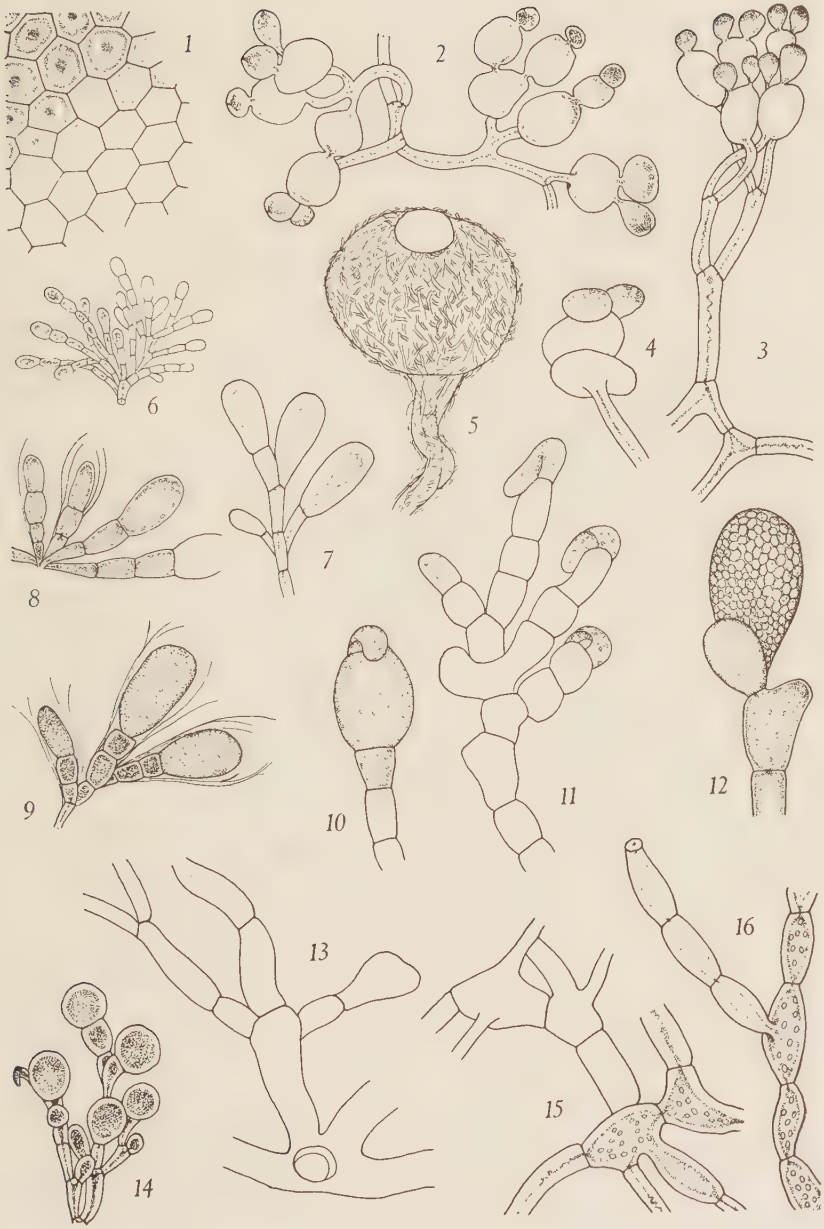
FIGS. 10-12. Hypertrophied carposporangial filaments containing starch grains. × 340

FIG. 13. Spermatangial filaments showing whorled branching. × 340

FIG. 14. Ultimate spermatangial filaments bearing spermatangia. × 610

FIG. 15. Medullary filaments with much enlarged cells containing starch grains at base of conceptacle. × 340

FIG. 16. Gonimoblast filaments at base of conceptacle. × 340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EXPLANATION OF PLATE III

Galaxaura oblongata

FIGS. 1, 14. Medullary filaments bearing cortical cells. × 340

FIG. 2. Regeneration of carposporangium. × 340

FIG. 3. Carposporangial filaments with young carposporangia. × 340

FIGS. 4–5. Carpospores showing variation in size. × 340

FIG. 6. Base of spermatangial filament with whorled branching. × 340

FIG. 7. Ultimate spermatangial filaments with spermatangia. × 610

FIG. 8. Ultimate spermatangial filaments with spermatangia. × 340

FIG. 9. Ultimate spermatangial filaments with young spermatangia. × 610

FIG. 10. Ultimate spermatangial filaments before spermatia are differentiated. × 340

FIG. 11. Gonimoblast filaments at base of female conceptacle. × 340

FIG. 12. Young vegetative filaments of apex of thallus. × 340

FIG. 13. Slightly older filaments below apex of thallus, showing development of cortical cells. × 340

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EXPLANATION OF PLATE IV

Galaxaura squalida

FIGS. 1–2. Section of portion of thallus, showing cortical tissue and extended assimilatory filaments. × 225

FIG. 3. Epidermal cells, surface view. × 225

FIG. 4. Surface of epidermis, showing circular cells bearing extended assimilatory filaments. × 225

FIG. 5. Cystocarp (pericarp) longitudinal section. × 225

FIGS. 6–7. Gonimoblast filaments with carposporangial branches bearing carposporangia at the distal ends. × 225

FIGS. 8–9. Carpogonial branches bearing carpogonia. × 225

FIG. 10. Extended assimilator, showing branching. × 225

FIG. 11. Basal and terminal parts of extended assimilatory filament. × 225

Galaxaura rugosa

FIG. 12. Epidermis surface view, showing angular epidermal cells and circular cells bearing extended assimilatory filaments. × 225

FIG. 13. Section of portion of thallus. × 225

Galaxaura glabriuscula

FIG. 15. Epidermis, surface view. × 225

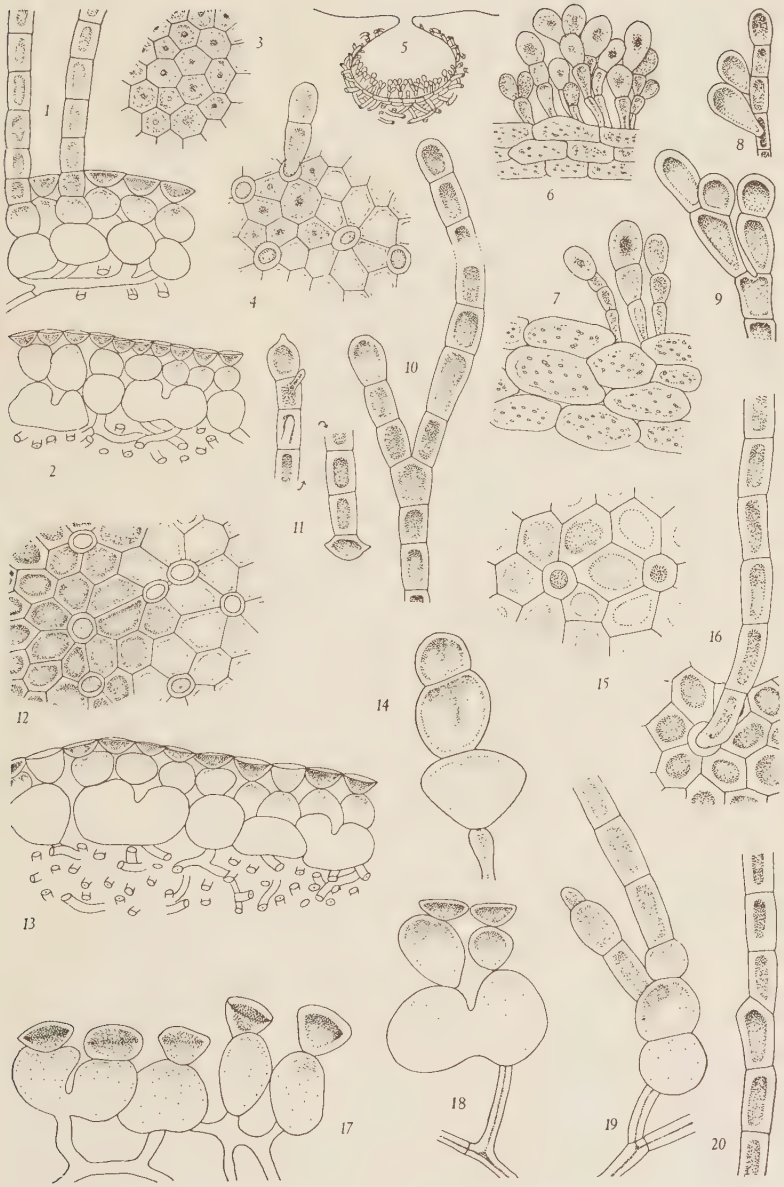
FIG. 16. Epidermis surface view, showing those circular cells among angular ones bearing extended assimilatory filaments. × 225

FIG. 17. Section of portion of thallus. × 225

FIGS. 14, 18. Cortical cells in relation to medullary filaments. × 225

FIG. 19. Extended assimilatory filaments in relation to cortical cells and medullary filaments. × 225

FIG. 20. Upper portion of extended assimilator, showing possible branching. × 225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EXPLANATION OF PLATE V

Galaxaura umbellata

FIG. 1. Section of portion of older thallus. × 340

FIG. 2. Surface view of epidermis. × 340

FIG. 3. Habit of part of plant. × 1

FIG. 4. Medullary filament. × 340

FIG. 5. Surface view of hypodermal layer of cells (intermediate layer of cortex), showing stellate chromatophores. × 340

FIG. 6. Section of portion of young thallus. × 340

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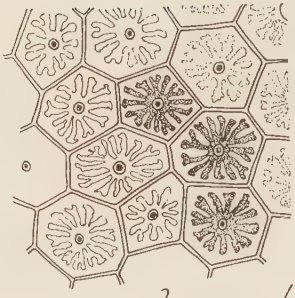

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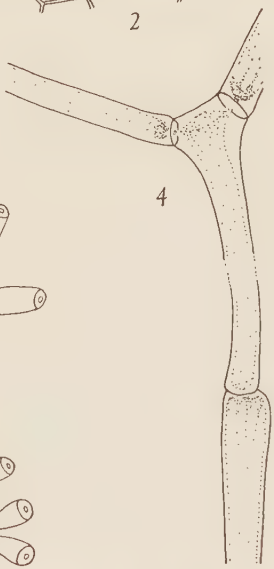

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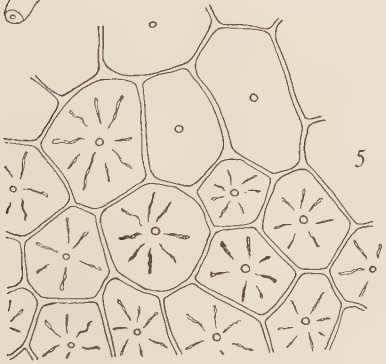

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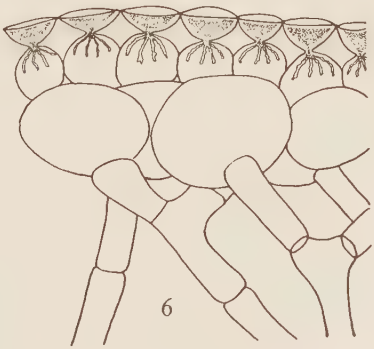

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EXPLANATION OF PLATE VI

Galaxaura veprecula

FIG. 1. Section of portion of thallus, showing epidermal cells bearing spinulose cells. × 340

FIG. 2. Section of portion of thallus without spinulose cells. × 340

FIG. 3. Extended assimilatory filament on the base of proliferation. × 195

FIG. 4. Surface view of epidermis. × 340

FIG. 5. Antheridial branch bearing spermatangia. × 340

FIG. 6. Two carposporangia. × 340

FIG. 7. Young secondary carposporangia with sheaths of old carposporangial walls. × 340

FIG. 8. Older stage of carposporangial branch with carposporangia. × 340

Galaxaura ventricosa

FIG. 9. Transverse section of thickened margin of thallus. × 195

FIG. 10. Section of portion of flattened side of thallus. × 340

FIG. 11. Surface view of epidermis. × 340

FIG. 12. Extended assimilatory filaments at the base of proliferations. × 195

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EXPLANATION OF PLATE VII

Galaxaura angustifrons

FIGS. 1–2. Section of portion of thallus. × 340

FIG. 3. Surface view of epidermis. × 340

FIG. 4. Extended assimilatory filaments. × 340

FIG. 5. Young extended assimilatory filaments. × 340

Galaxaura intermedia, sp. nov.

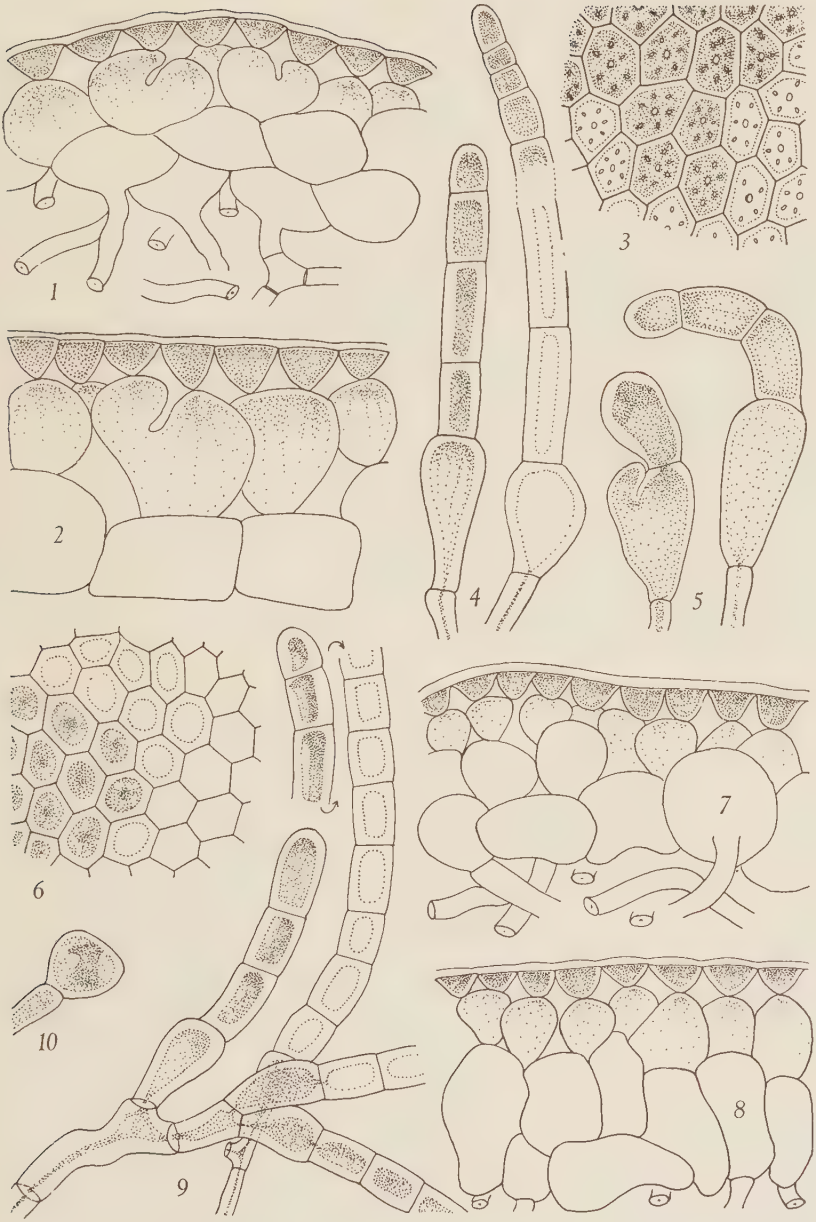
FIG. 6. Surface view of epidermis. × 340

FIG. 7. Section of portion of thallus. × 340

FIG. 8. Section of portion of thallus at the thickened margin. × 340

FIG. 9. Extended assimilatory filaments. × 340

FIG. 10. Young developing extended assimilatory filament. × 340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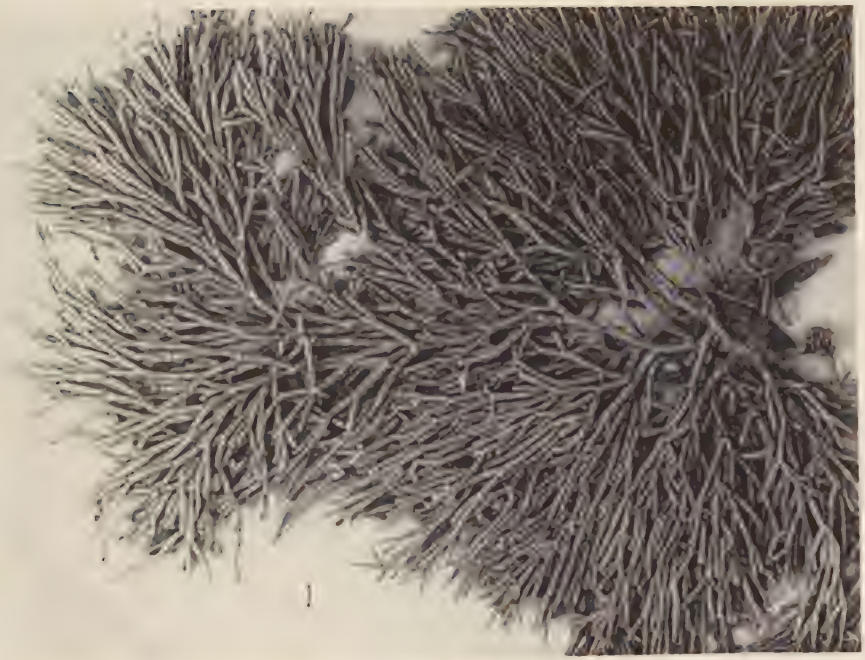
EXPLANATION OF PLATE VIII

FIG. 1. *Galaxaura cylindrica; Bartlett 14981*, Dalupiri Island, Babuyan Group, P. I. × 1

FIG. 2. *Galaxaura squalida; Villaflores 6, 8*, Mindoro Province. P. I. × 1.1



EXPLANATION OF PLATE IX

FIG. 1. *Galaxaura oblongata*, male plant; *Bartlett 16185*, Liloan Beach, Cebu Island, P. I. × 1.1

FIG. 2. *Galaxaura oblongata*, female plant; *Bartlett 14980*, Dalupiri Island, Babuyan Group, P. I. × 1

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EXPLANATION OF PLATE X

FIG. 1. *Galaxaura glabriuscula; Kostermans 254*, Eiland Kĕlapa, Duizend-eilanden, Java. × 1.2

FIG. 2. *Galaxaura rugosa; Bartlett 15410*, Batan Island, P. I. × 1.3

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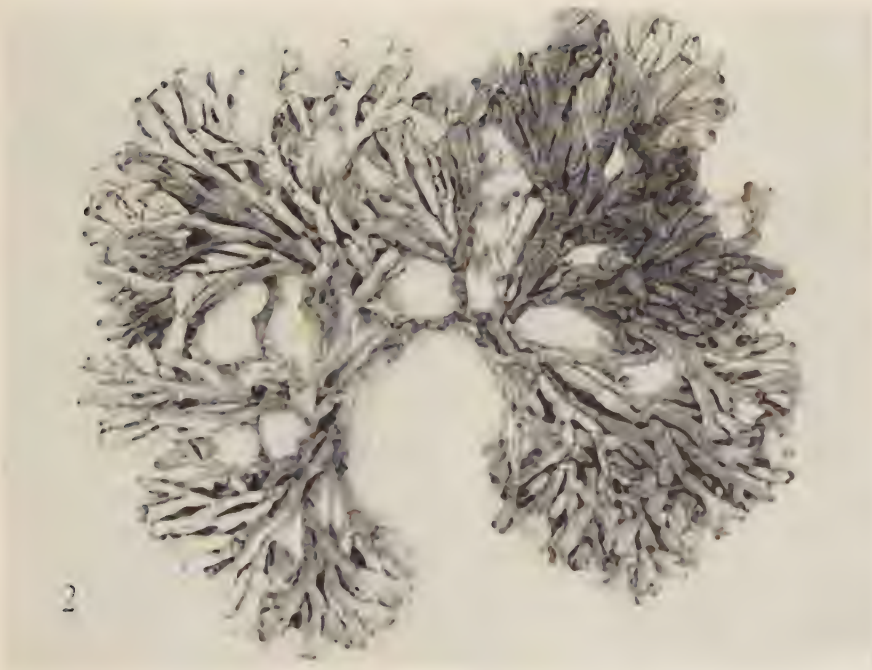
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EXPLANATION OF PLATE XI

FIG. 1. *Galaxaura umbellata; Bartlett 15022*, Dalupiri Island, Babuyan Group, P. I. × 1.25

FIG. 2. *Galaxaura angustifrons; Taylor 81–33*, Isla Santa Cruz, Ecuador. × 1.5

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EXPLANATION OF PLATE XII

FIG. 1. *Galaxaura veprecula; Bartlett 15009b*, Dalupiri Island, Babuyan Group, P. I. × 1

FIG. 2. *Galaxaura ventricosa; Taylor 39–652*, Isla María Magdalena, Mexico. × 1

EXPLANATION OF PLATE XIII

Galaxaura intermedia Chou, sp. nov.; *Taylor 34–213* (TYPE), Isla Santa María, Galápagos Islands, Ecuador. × 0.75